CLAIMS

What is claimed is:

1. A method, comprising:

filtering a scanned image to obtain a transformed image, wherein the transformed image comprises a series of substantially parallel lines of alternating binary pixel values; and

determining an orientation angle of the scanned image using properties of the transformed image.

2. The method of claim 1, wherein filtering a scanned image to obtain a transformed image comprises applying a linear shift invariant filter to the scanned image to remove meaningful picture information from the scanned image.

3. The method of claim 1, wherein determining an orientation angle of the scanned image using properties of the transformed image comprises:

estimating a number of changes in binary pixel values along one or more rows of the transformed image;

estimating a number of changes in binary pixel values along one or more columns of the transformed image; and

determining an orientation angle using the arctangent of the number of changes in binary values along one or more columns divided by the number of changes in binary values along one or more rows.

4. The method of claim 1, further comprising subtracting a printing angle from the orientation angle to estimate a rotation angle.

5. The method of claim 1, wherein determining an orientation angle of the scanned image using properties of the transformed image comprises:

generating a matrix, z, wherein z comprises rows of uniform binary values, and

wherein the binary values of one row differ from the binary values of the remaining rows;

for a series of angles θ_i, wherein $\theta_{min} \leq \theta_i \leq \theta_{max}$, repeating the operations:

generating a transformed matrix z_θ by rotating the matrix z through θ_i degrees;

generating at least one set of coordinates (x_θ, y_θ);

computing a correlation function between the binary values of the transformed image and the image z_θ positioned at (x_θ, y_θ) of the transformed image; and

selecting the angle θ_i that maximizes the correlation function.

6. The method of claim 1, further comprising estimating a translation amount of the scanned image, wherein estimating a translation amount comprises:

subtracting a printing angle from the orientation angle to estimate a rotation angle;

rotating the scanned image through the rotation angle; and

determining an (x, y) coordinate set that maximizes a correlation between a portion of the scanned image and an original digital image.

7. A computer-readable medium comprising computer-executable instructions that, when executed, direct a computer to:

remove meaningful image information from a scanned image to generate a transformed image; and

determine an orientation angle of the scanned image using the transformed image.

8. The computer readable medium of claim 7, further comprising computer-executable instructions that, when executed, direct a computer to apply a linear shift invariant filter to the scanned image to remove meaning image information from the scanned image.

9. The computer readable medium of claim 7, wherein the instructions for determining an orientation angle of the scanned image using properties of the transformed image comprise computer-executable instructions that, when executed, direct a computer to determine an orientation angle using the estimated periodicity of changes in binary pixel values along one or more rows of the transformed image and the estimated periodicity of changes in binary pixel values along one or more columns of the transformed image.

10. The computer readable medium of claim 7, further comprising computer-executable instructions that, when executed, direct a computer to subtract a printing angle from the orientation angle to estimate a rotation angle.

11. The computer readable medium of claim 7, wherein instructions for determining an orientation angle of the scanned image using the transformed image comprise computer-executable instructions that, when executed, direct a computer to determine an angle that maximizes a correlation function between the intersection of the transformed image and a matrix of binary values comprising at least one array of uniform binary values.

12. The computer readable medium of claim 7, wherein instructions for determining an orientation angle of the scanned image using properties of the transformed image comprise computer-executable instructions that, when executed, direct a computer to:

generate a binary matrix, z, wherein z comprises rows of uniform binary values, and wherein the binary values of one row differ from the binary values of the remaining rows;

for a series of angles θ_i, wherein $\theta_{min} \leq \theta_i \leq \theta_{max}$:

generate an image z_θ by rotating z through θ_i degrees;

generate at least one set of coordinates (x_θ, y_θ);

compute a correlation function between the binary values of the transformed image and the image z_θ positioned at (x_θ, y_θ) of the transformed image; and

select the angle θ_i that maximizes the correlation function.

13. The computer readable medium of claim 7, further comprising instructions for estimating a translation amount of the scanned image that, when executed, direct a computer to:

subtract a printing angle from the orientation angle to estimate a rotation angle;

rotate the scanned image through the rotation angle; and

determine an (x, y) coordinate set that maximizes a correlation between a portion of the scanned image and an original digital image.

14. A method of determining a translation amount between a first image h of size (m×m) and second image z of size (n×n), where m>n, the method comprising:

computing a correlation value between the second image z and a subimage of the first image h at a plurality of (x, y) coordinate sets of the first image h;

storing correlation values and the associated (x, y) coordinate set in a suitable memory location; and

determining the (x, y) coordinate set that maximizes the correlation value.

15. The method of claim 14, wherein computing a correlation value between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h comprises:

defining a subimage $h^{(t,u)}$ of the image h, wherein each coordinate $h^{(t,u)}(i, j)$ is equal to $h^{(t+i,\, u+j)}$; and

iteratively calculating, for each value of $i \leq n$, $j \leq n$, $u \leq (m-n)$ and $t \leq (m-n)$:

$$S_{(t,u)} = S + [h^{(t,u)}(i,j) - z(i,j)]^2 .$$

16. The method of claim 15, wherein determining the (x, y) coordinate set that maximizes the correlation value further comprises selecting the (i, j) coordinate set associated with the minimum value of the iteratively calculated values of $S_{(t,u)}$.

17. The method of claim 14, wherein computing a correlation value between the image z and a subimage of the image h at each (x, y) coordinate set of the image h comprises:

defining a first derivative image $\tilde{z}$ of the image z, wherein:

$\tilde{z}$ is of size (k×k), and

k<n;

defining a subimage $h^{(t,u)}$ of the image h, wherein each coordinate $h^{(t,u)}(i, j)$ is equal to h(t+i, u+j);

defining a second derivative image $\tilde{h}^{(t,u)}$ of the subimage h, wherein $\tilde{h}$ is of size (k×k), where k<n; and

iteratively calculating, for each value of $i \leq k$, $j \leq k$, $u \leq (m-n)$ and $t \leq (m-n)$:

$$S_{(t,u)} = S + [\tilde{h}^{(t,u)}(i,j) - \tilde{z}(i,j)]^2 .$$

18. The method of claim 17, wherein determining the (x, y) coordinate set that maximizes the correlation value further comprises selecting the (i, j) coordinate set associated with the minimum value of the iteratively calculated values of $S_{(t,u)}$.

19. The method of claim 17, wherein:

defining a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size (k×k), where k<n, comprises locally averaging the image z by a factor p, where p·k=n; and

defining a second derivative image $\tilde{h}^{(t,u)}$ of the subimage h, wherein $\tilde{h}$ is of size (k×k), where k<n, comprises locally averaging h by a factor p, where p·k=n.

20. The method of claim 14, wherein computing a correlation value between the image z and a subimage of the image h at each (x, y) coordinate set of the image h comprises:

defining a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size (k×k), where k<n;

defining a second derivative image $\tilde{h}$ of the subimage h, wherein $\tilde{h}$ is of size (l×l);

determining a coordinate set $(\hat{x}_{10}, \hat{y}_{10})$ that maximizes a correlation between $\tilde{h}$ and $\tilde{z}$;

using the coordinate set $(\hat{x}_{10}, \hat{y}_{10})$ to determine a coordinate set $(\hat{x}_{20}, \hat{y}_{20})$ that maximizes a correlation between h and z.

21. The method of claim 20, wherein:

defining a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size $(k \times k)$, where $k<n$, comprises locally averaging the image z by a factor p, where $p \cdot k=n$; and

defining a second derivative image $\tilde{h}$ of the image h, wherein $\tilde{h}$ is of size $(l \times l)$, where $l<n$, comprises locally averaging the image h by a factor p, where $p \cdot l=n$.

22. A computer-readable medium having computer-executable instructions that, when executed, direct a computer to determine a translation amount between a first image h of size $(m \times m)$ and second image z of size $(n \times n)$, where $m>n$, by performing operations comprising:

comparing correlation values between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h; and

determining the (x, y) coordinate set that maximizes the correlation value.

23. The computer readable medium of claim 22, wherein the instructions for comparing correlation values between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h comprise instructions that, when executed, cause a computer to:

position the image z at an (x, y) coordinate set corresponding to the upper-left corner of the image h; and

execute a nested loop that repeatedly:

computes a correlation value between the image z and a subimage of the image h at a current (x, y) coordinate set of the image h; and

increments a value in the (x, y) coordinate set.

24. The computer readable medium of claim 23, wherein the instructions that compute a correlation value between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h comprise instructions that:

define a subimage $h^{(t,u)}$ of the image h, wherein each coordinate $h^{(t,u)}(i, j)$ is equal to $h^{(t+i,\ u+j)}$; and

iteratively calculate, for each value of $i \leq n$, $j \leq n$, $u \leq (m-n)$ and $t \leq (m-n)$:

$$S_{(t,u)} = S + [h^{(t,u)}(i,j) - z(i,j)]^2 .$$

25. The computer readable medium of claim 24, wherein determining the (x, y) coordinate set that maximizes the correlation value further comprises selecting the (i, j) coordinate set associated with the minimum value of the iteratively calculated values of $S_{(t,u)}$.

26. The computer readable medium of claim 22, wherein the instructions for comparing correlation values between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h comprise instructions that, when executed, cause a computer to:

define a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size (k×k), where k<n;

define a subimage $h^{(t,u)}$ of the image h, wherein each coordinate $h^{(t,u)}(i, j)$ is equal to h(t+i, u+j);

define a second derivative image $\tilde{h}^{(t,u)}$ of the subimage h, wherein $\tilde{h}$ is of size (k×k), where k<n; and

iteratively calculate, for each value of $i \leq k$, $j \leq k$, $u \leq (m-n)$ and $t \leq (m-n)$:

$$S_{(t,u)} = S + [\tilde{h}^{(t,u)}(i,j) - \tilde{z}(i,j)]^2 .$$

27. The computer readable medium of claim 26, wherein determining the (x, y) coordinate set that maximizes the correlation value further comprises selecting the (i, j) coordinate set associated with the minimum value of the iteratively calculated values of $S_{(t,u)}$.

28. The computer readable medium of claim 26, further comprising instructions that, when executed, cause a computer to:

locally average the image z by a factor p, where $p \cdot k=n$ to define a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size $(k \times k)$, where $k<n$, comprises; and

locally average the image h by a factor p, where $p \cdot k=n$ to define a second derivative image $\tilde{h}^{(t,u)}$ of the subimage h, wherein $\tilde{h}$ is of size $(k \times k)$, where $k<n$.

29. The computer readable medium of claim 22, wherein the instructions for comparing correlation values between the image z and a subimage of the image h at a plurality of (x, y) coordinate sets of the image h comprise instructions that, when executed, cause a computer to:

define a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is of size $(k \times k)$, where $k<n$;

define a second derivative image $\tilde{h}$ of the subimage h, wherein $\tilde{h}$ is of size $(l \times l)$;

determine a coordinate set $(\hat{x}_{10}, \hat{y}_{10})$ that maximizes a correlation between $\tilde{h}$ and $\tilde{z}$; and

use the coordinate set $(\hat{x}_{10}, \hat{y}_{10})$ to determine a coordinate set $(\hat{x}_{20}, \hat{y}_{20})$ that maximizes a correlation between h and z.

30. The computer readable medium of claim 29, further comprising instructions that, when executed, cause a computer to:

locally average the image z to define a first derivative image $\tilde{z}$ of the image z, wherein $\tilde{z}$ is smaller than z; and

locally average the image h to define a second derivative image $\tilde{h}$ of the image h, wherein $\tilde{h}$ smaller than h.

31. A method of estimating a rotation amount and translation coordinates for a scanned image of a printed copy of an original digital image, wherein the original digital image comprises a logo of known dimensions surrounded by a border of known dimensions, comprising:

scaling the scanned image by a sizing factor to create a scaled image that has the same dimensions as the original digital image;

rotating the scaled image through a range of angles, and at each rotation angle:

computing a rowsum difference vector;

computing a columnsum difference vector;

applying a threshold to the rowsum vector and the columnsum vector to select a plurality of candidate (x, y) coordinate locations;

computing a correlation value between the scaled image and the original digital image at the plurality of candidate (x, y) coordinate locations;

storing the (x, y) coordinate location and the rotation angle associated with the maximum correlation value in a memory location; and

selecting from the memory location the (x, y) coordinate set and rotation angle associated with the maximum correlation value.

32. The method of claim 31, wherein scaling the scanned image by a sizing factor to create a scaled image that has the same dimensions as the original digital image comprises applying a threshold function to the scanned image.

33. The method of claim 31, wherein computing a rowsum difference vector comprises:

calculating a sum of pixel values for a plurality of rows of the scaled image to form a rowsum vector; and

subtracting elements of the rowsum vector offset by a predetermined amount.

34. The method of claim 31, wherein computing a columnsum difference vector comprises:

calculating a sum of pixel values for a plurality of columns of the scaled image to form a columnsum vector; and

subtracting elements of the columnsum vector offset by a predetermined amount.

35. The method of claim 31, wherein computing a correlation value between the scaled image and the original digital image at the plurality of candidate (x, y) coordinate locations comprises at least one of:

computing an element-by-element multiplication of the original digital image and a section of the scaled image positioned at the candidate (x, y) coordinate locations; and

computing the L2 norm of an error between the original digital image and a section of the scaled image positioned at the candidate (x, y) coordinate locations.

36. The method of claim 31, further comprising computing a correlation value between the scaled image and the original digital image at a plurality of (x, y) coordinates in a confidence region surrounding the plurality of candidate (x, y) coordinate locations.

37. The method of claim 31, further comprising restoring the scaled image to its original dimensions and computing a correlation value between the restored image restored to its original dimensions and the original digital image at a plurality of (x, y) coordinates in a confidence region surrounding the plurality of candidate (x, y) coordinate locations.

38. A computer readable medium having computer executable instructions that, when executed, direct a computer to estimate a rotation amount and translation coordinates for a scanned image of a printed copy of an original digital image, wherein the original digital image comprises a logo of known dimensions surrounded by a border of known dimensions, by performing operations comprising:

scaling the scanned image by a sizing factor to create a scaled image that has the same dimensions as the original digital image;

calculating a plurality of correlation values between the original digital image and the scaled, scanned image positioned at a plurality of orientation angles and (x, y) coordinate pairs;

storing each calculated correlation value in association with the orientation angle and the (x, y) coordinate pair; and

selecting from the memory location the (x, y) coordinate set and rotation angle associated with the maximum correlation value.

39. The computer readable medium of claim 38, wherein calculating a plurality of correlation values between the original digital image and the scaled, scanned image positioned at a plurality of orientation angles and (x, y) coordinate pairs comprises:

rotating the scaled image through a range of angles, and at each rotation angle:

computing a rowsum difference vector;

computing a columnsum difference vector;

applying a threshold to the rowsum vector and the columnsum vector to select a plurality of candidate (x, y) coordinate locations;

computing a correlation value between the scaled image and the original digital image at the plurality of candidate (x, y) coordinate locations; and

storing the (x, y) coordinate location and the rotation angle associated with the maximum correlation value in a memory location.

40. The computer readable medium of claim 38, wherein scaling the scanned image by a sizing factor to create a scaled image that has the same dimensions as the original digital image comprises applying a threshold function to the scanned image.

41. The computer readable medium of claim 39, wherein computing a rowsum difference vector comprises:

calculating a sum of pixel values for a plurality of rows of the scaled image to form a rowsum vector; and

subtracting elements of the rowsum vector offset by a predetermined amount.

42. The computer readable medium of claim 39, wherein computing a columnsum difference vector comprises:

calculating a sum of pixel values for a plurality of columns of the scaled image to form a columnsum vector; and

subtracting elements of the columnsum vector offset by a predetermined amount.

43. The computer readable medium of claim 39, wherein computing a correlation value between the scaled image and the original digital image at the plurality of candidate (x, y) coordinate locations comprises at least one of:

computing an element-by-element multiplication of the original digital image and a section of the scaled image positioned at the candidate (x, y) coordinate locations; and

computing the L2 norm of an error between the original digital image and a section of the scaled image positioned at the candidate (x, y) coordinate locations..

44. The computer readable medium of claim 39, further comprising computing a correlation value between the scaled image and the original digital image at a plurality of (x, y) coordinates in a confidence region surrounding the plurality of candidate (x, y) coordinate locations.

45. The computer readable medium of claim 38, further comprising restoring the scaled image to its original dimensions and computing a correlation value between the restored image restored to its original dimensions and the original digital image at a plurality of (x, y) coordinates in a confidence region surrounding the plurality of candidate (x, y) coordinate locations.